ISSUE 2 / 2009

DATA – FACTS – ANALYSIS

CUTEC-News

BTL AND MORE: THE RESURGENCE OF FT SYNTHESIS

CONFLICTING GOALS

Conflicting goals are a fact of life, and they confront us everywhere we turn. We find them in the biblical story of Abraham (1st Book of Moses, 22, 1-14), and to this day they represent formidable challenges for the political and business community. Conflicting goals create a conflict of interest, because achievement of one goal makes it more difficult to achieve another goal. To cite one typical example, minimisation of procurement costs and minimisation of interest and inventory costs are conflicting goals. The conflict can only be resolved by optimising economic order quantities. Admittedly, this particular conflict does not affect us directly, but we do face conflicting goals in our research activities, for example the conflict between energy efficiency and emission limits. Technologies often have to be modified to comply with more stringent statutory emission limits, and the changes frequently have an impact on energy efficiency. In practice, this normally translates to higher consumption of energy or auxiliary materials. One example from the automotive industry shows that this does not necessarily have to be the case. On one of our current research projects, modification of a high-volume car body painting line reduced energy consumption by more than 35%, and emission levels are also well below the maximum limits. In this instance, we succeeded in resolving the conflict between energy efficiency and emission levels. We will share more information with you about this technology in an upcoming issue.

In this issue we will be shining the spotlight on chemical process engineering. A report on biogas reforming appears on page 3. On page 2 we tell you about the decentralised Fischer-Tropsch synthesis research project. Shortly before the editorial deadline, we received a brief report on the 2nd Fuel Cell Summer School which took place at the end of September. The report appears likewise on page 2. Finally, I highly recommend that you read the article written by Dr. Lindermeir who summarises the results of his work since he took charge of the Chemical Process Engineering Department two years ago.

Otto Carlowitz

P.S.: Just publishing each issue of CUTEC News creates a minor "conflict of interest". The editorial team is committed to editorial deadlines, but this often does not harmonise with the interests of the authors who are deeply involved in scientific work. There is no easy answer to the problem, but we always manage to find a solution. The fact that you are holding this issue in your hands should be proof enough.

2ND LOWER SAXONY FUEL CELL SUMMER SCHOOL A BIG SUCCESS

CUTEC was a co-organiser of the Fuel Cell Summer School which was held on September 28th – October 2nd in the Turbo Machine and Fluid Dynamics Institute (TFD) at the University of Hannover. The only input we received before we went to press was a photograph of the group that attended the event. An in-depth review of the Summer School is scheduled to appear in the next issue of CUTEC. All we will say at this point is that the response to the event was excellent. (he)

DECENTRALISED FISCHER-TROPSCH SYNTHESIS

Biomass conversion is a major feature on the CUTEC strategic roadmap. Further development work on Fischer-Tropsch (FT) synthesis for decentralised systems will help us achieve our strategic goals. The main feature of these decentralised concepts is the use of a reformer to reduce the diversity of products from the synthesis process.

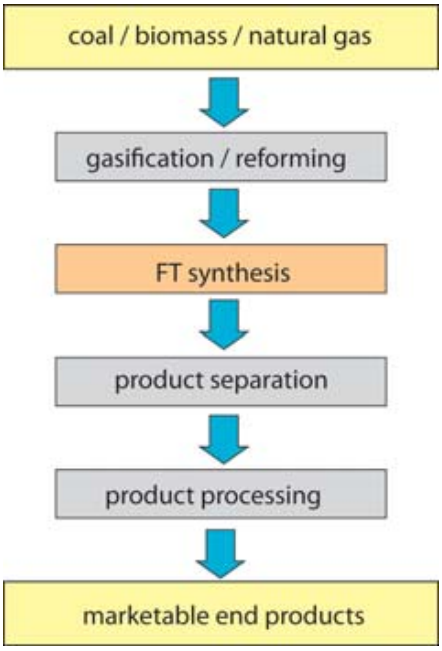


Fig. 1: Key steps in the overall FT synthesis process chain

The process sequence for converting raw materials (coal, biomass and natural gas) into a finished product using FT synthesis is shown in Fig. 1.

The first step is gasification or reforming to produce and purify the syngas (a mixture of hydrogen and carbon monoxide). Carbon monoxide and hydrogen are catalytically combined in an FT reactor to form hydrocarbon chains of varying lengths. The hydrocarbons are separated out and processed until they meet market requirements. Fuels, for example, have to meet specific octane or cetane ratings to comply with applicable standards.

Fig. 2 lists the major FT crude products. The ratios are not listed, because they depend on the catalytic conversion

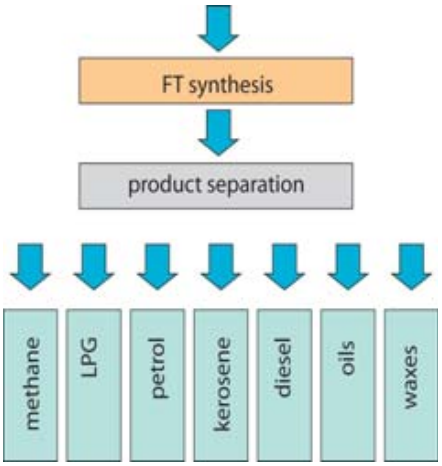


*Fig. 2: Idealised FT synthesis product distribution (*processing required prior to marketing)*

process and operating conditions. With this process, it is not possible to synthesise only a single product.

Fig. 2 indicates that FT synthesis as shown on the flow chart in Fig. 1 initiates processes that normally occupy the major part of a conventional refinery. This is not compatible with compact system design which is intended for decentralised sources of biomass. One way around the problem is to use the approach show in Fig. 3, which is suitable for decentralised synthesis.

What sets this concept apart is the fact that as many as possible of the by-products, which cannot be used locally, are fed into the reformer for re-use as input material. Admittedly, there are losses associated with recycling of the unavoidable by-products, but at least this approach eliminates the need for inefficient refining and marketing of fractions which are only present in small volumes. In the recycling process, care must be taken to ensure that CO_2 produced during reforming does not have a negative impact on synthesis. CO_2 separation is technically possible, but it would conflict with the goal of keeping the system as simple as possible.

The practical feasibility of using this approach to produce FT wax is being analysed on a project which is currently in progress. The work, which is based on experimental trials and evaluation of the service life of the FT catalytist under the given conditions, is primarily focused on optimisation of the recycling rate to the reformer.

As shown in Fig. 1, syngas can be produced from fossil and renewable resources using FT synthesis. From the technical standpoint, methane (the main constituent of natural gas) is the ideal input material. The obvious approach is to use natural gas during the initial implementation phase. Users can then migrate to renewable raw materials:

- the pilot plant processes natural gas
- the production plant uses biomethane partially or exclusively as the raw material

Thermal syngas production (e.g. biomass gasification) is a possible alternative or supplemental process. This type of progressive approach is crucial for SMEs who need to minimise the development risks.

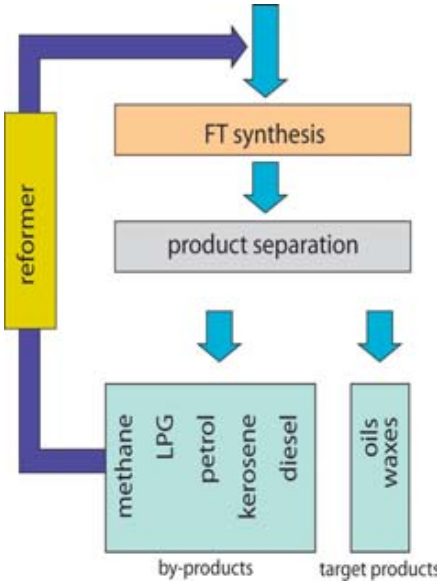
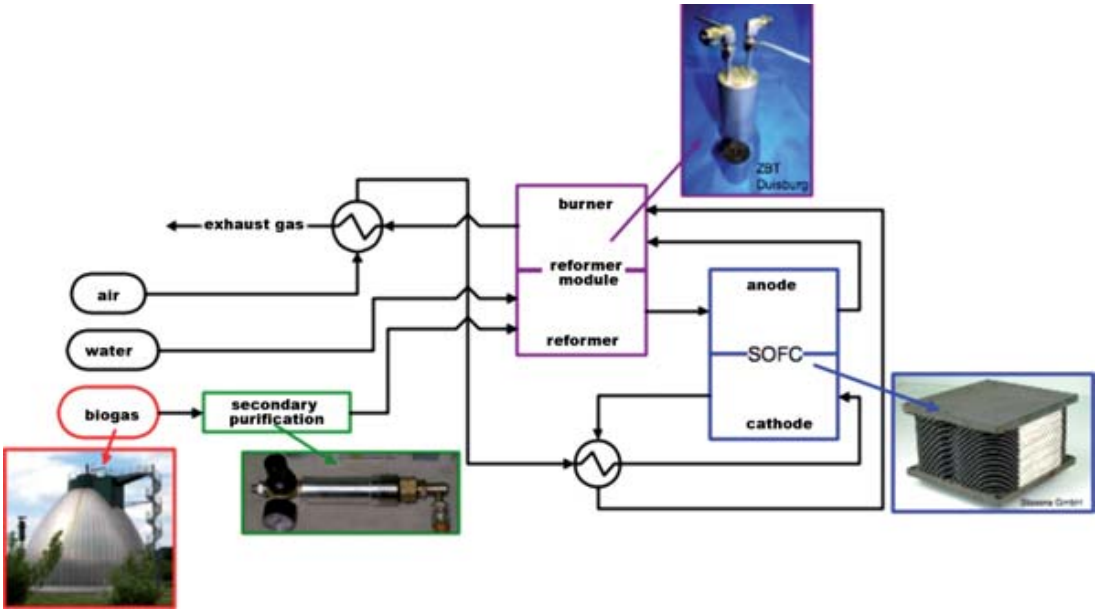


*Fig. 3: FT wax synthesis with by-product recycling to reformer (*refining required prior to marketing)*

CUTEC is currently running a project to demonstrate the feasibility of FT synthesis on a pilot scale and to assess the cost-effectiveness. We are working closely with an SME which is interested in processing and marketing the products. (bk)

BIOGAS TO ELECTRICITY USING SOFCS

Innovative system design enhances efficiency



System diagram including the main subsystems

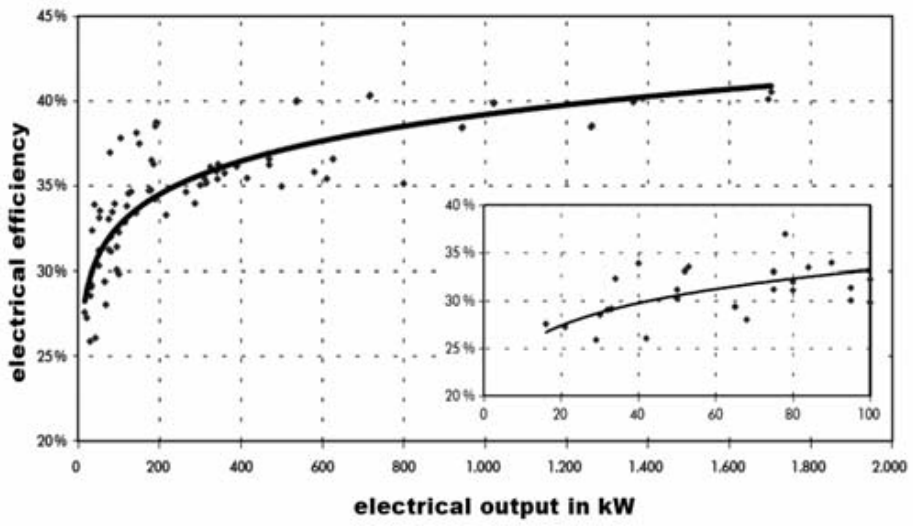
The main components of biogas are methane and carbon dioxide, generated during anaerobic biomass digestion. Biogas production as a source of renewable energy continues to grow. Since the process only releases CO_2 that was captured during plant growth, no additional CO_2 is released into the atmosphere. At present, biogas is primarily used to produce electricity by combined heat and power plants (CHPs). The electricity is fed into the grid or used to supply local demand. CHP electrical efficiency is limited to 25% – 40% depending on the size of the cogeneration plant. Large plants are significantly more efficient than smaller ones (see figure below). For small scale CHPs investment and operating costs increase disproportionally. Generally speaking, large generation plants are the more attractive option.

Fuel cell systems provide an alternative route to biogas electrification, especially high-temperature SOFC with it's high electrical efficiency look promising for the future. To be used in SOFCs, biogas has to be converted (reformed) into a mixture of hydrogen and carbon monoxide in an upstream process, which is then fed as fuel gas to the SOFCs. Reforming usually involves conversion of methane using water and/or atmospheric oxygen, causing complicated process equipment and efficiency losses.

To offset these disadvantages, an alternative system design was developed in conjunction with the Zentrum fuer BrennstoffzellenTechnik (ZBT GmbH, Duisburg). CUTEC and ZBT have now turned this concept into a common project, which is funded by the Federal Ministry of Economics and Technology. Following sufficient pre-purification of the biogas, the methane in the biogas is converted using the inherent CO_2 resulting in very high syngas yields. The reformate gas is fed to the SOFC and is efficiently converted into electricity without the need to supply air. To avoid the risk of soot formation and to ensure stable operation despite variations in the biogas composition, water can be fed into the system. The illustration above shows a diagram of the proposed system with its main subsystems. Process simulation shows that the overall electrical efficiency of these systems can be as high as 45%. This level of efficiency is not achievable with conventional technology, especially in small-scale power generation.

During the course of the 2½ year project, CUTEC and ZBT will develop, build and characterise a system based on this technology. Well-known industrial partners in the fuel cell and biogas systems industry will provide project support. The partners (including Umicore, Staxera, Nordzucker and Biogas Nord) will sit on an advisory committee, which will ensure that the new techniques are suitable for practical application.

An SOFC fuel cell rated at 1 kWel will be used to demonstrate the basic feasibility and efficiency advantages of the overall system. The system will be installed in 2011 at an existing Nordzucker biogas plant for final functional verification. If the results are successful, the concept can be scaled up afterwards. (li)



Electrical efficiency of combined heat and power plants

*Solid Oxide Fuel Cell

PROFILE:

NEW MAN AT THE HELM OF CHEMICAL PROCESS ENGINEERING FOR THE PAST 2 YEARS

Dr. Andreas Lindermeir took charge of Chemical Process Engineering on May 1st, 2007. Right from the start, good strategic positioning and excellent support from the experienced team of the department made it easier for Dr. Lindermeir to phase into his new role. Projects already in progress at the time were brought to a successful conclusion, and new project resources were acquired in a short space of time.

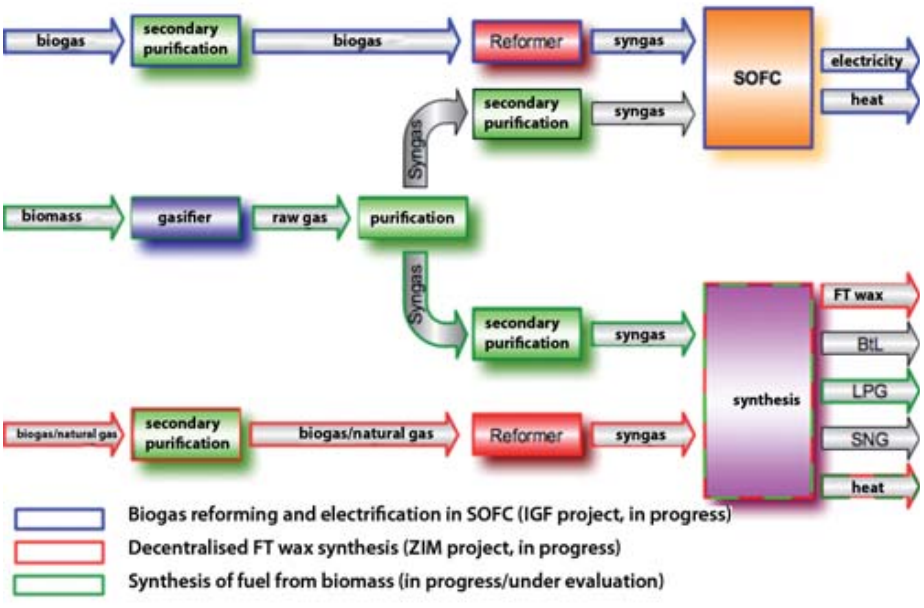
During the continuous strategic review, the CUTEC Scientific Advisory Committee agrees to the proposed main working areas that the department will be taking:

- innovative system technology and SOFC fuel cell component development
- synthesis of renewable fuels and chemical feedstock ased on biomass.

Chemical Process Engineering team

At first glance, these two areas of activity appear to have little in common. However when you take a closer look, you soon realise that there are significant synergies, as the following three examples show (see illustration below).

Within a joint research project[1] together with the Center for Fuel Cell Technology (ZBT GmbH) in Duisburg, biogas is purified and the methane is converted with the CO_2 which is present in the biogas to produce synthetic gas (syngas) in an innovative catalytic reforming process. The syngas is subsequently converted to electricity (and heat) in a high-efficiency SOFC fuel cell system, build by CUTEC. Read the report on Page 3 to learn more about this project. The concept enables electrical efficiency ratings in excess of 40%, something which is not achievable with conventional small-scale cogeneration plants.



Examples of current Chemical Process Engineering projects and networking

The department is also involved in another publicly subsidised project[2] which is looking at the synthesis of high-quality Fischer-Tropsch (FT) wax based on natural gas . The intention in the medium term is to replace natural gas with biogas as the feedstock. Once again, upstream purification stages ensure the quality of gas needed for catalytic reforming. The syngas produced is then converted in an FT synthesis process to commercial-grade FT wax.

We are also working on biomass-based synthesis of renewable fuels. With the support of the Thermal Process Engineering Department, we are adapting synthesis technology to convert processed syngas made from biomass into LPG, FT diesel and SNG.

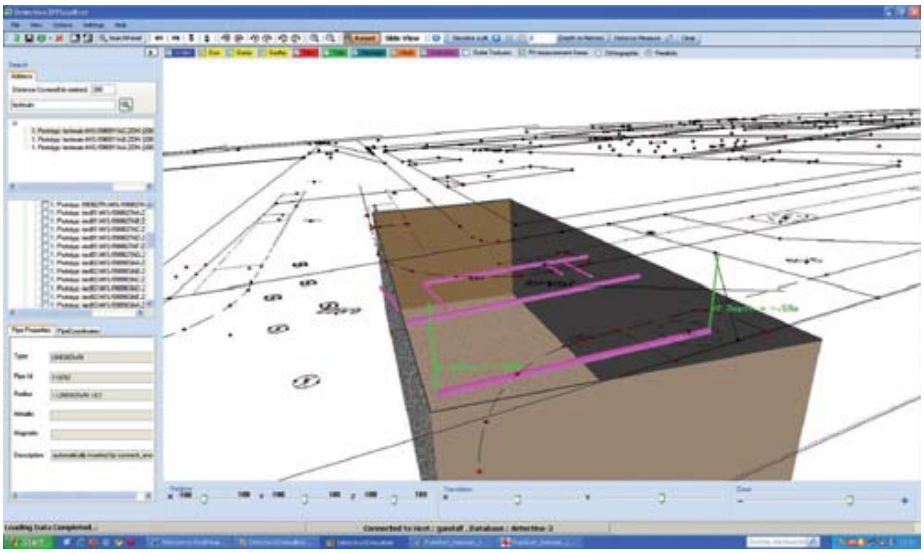
All three process sequences include similar steps, e.g. purification, reforming and synthesis, and we have experience with this technology from other projects. The knowledge base which the department has built up includes expertise which is easily transferrable between a variety of processes and projects.

We currently have 6 full-time employees in the department (one manager, four scientists and one machinist). We receive additional support from CUTEC central services (e.g. analytical and workshop services) and from students who

Continued on page 8

[1]Subsidised by the Federal Ministry of Economics and Technology through the German Federation of Industrial Research Association's IGF programme to promote joint industrial research and development
[2]Subsidised by the Federal Ministry of Economics and Technology through the German Federation of Industrial Research Association's Central SME Innovation Programme (ZIM

DETECTINO – A JOINT PROJECT TO ENHANCE TOMORROW'S BURIED UTILITY LINE INSTALLATION AND ROAD WORKS

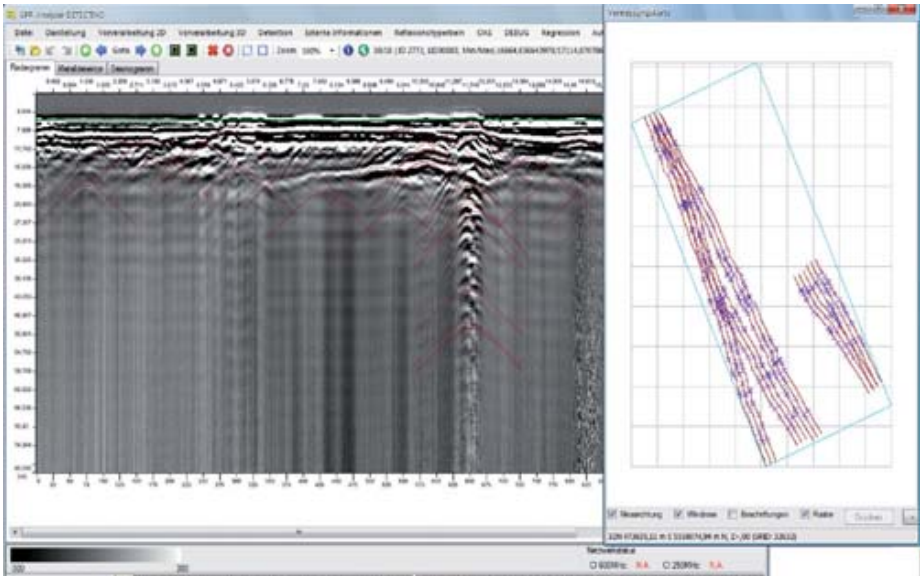


3D visualisation of an area beneath a road showing all buried lines

Every year, digging causes millions of euros worth of damage to buried utility lines. Given the level of the problem and in view of the fact that in many cases little or no documentation is available on the buried lines, Clausthaler Umwelttechnik-Institut GmbH, the University of Frankfurt Geophysical Institute, the machinery producer ProKasro and Detectino GmbH formed a consortium in 2007 to address the issue. The consortium is working on a versatile, cost-effective mobile device which is able to quickly detect buried utility line networks in a wide variety of situations. Using a DIN-based object type code, the lines will be identified and their location and depth will be determined with centimeter accuracy. The data will then be entered into the underground network maps.

The Detectino system has been under development for the past three years based on this requirements profile. It features ground radar antennas, metal detectors and electromagnetic probes which are all mounted on a mobile platform that is small enough for utility line detection on footpaths. The sensor array is connected to a standard PC. New computer intelligence technology processes the input data and creates a virtual image of the area underground down to a depth of 4 meters.

The following requirements were particularly challenging on this project: non-contact sensing, location accuracy in the centimetre range using differentiated GPS and provision of position and depth information which can be used to update existing mapping and support 2D or 3D display. In addition, the work has to be carried out on site using a DIN-based object type code, which is a major difference compared to all of the systems which have been available up to this point. For the first time, it will now be possible for the operator to see the results live in a user-friendly visualisation and navigate underground with the mouse.



CI-based radargram analysis

The main target groups for this type of documentation are:

- companies that install buried utility lines
- electricity, water, sewage, gas and communications network operators
- the insurance industry
- companies that are responsible for digging up, repairing or installing new lines

local government and other agencies that have a vital interest in:

- more efficient resource planning (personnel and equipment) based on knowledge of the situation underground
- a mechanism to disable digging equipment when it comes too close to lines that have been detected
- efficient (fast), cost-effective survey of critical or unknown areas to assess risks (leaks, flaws, etc.).
- verification or completion of existing maps
- ability to narrow down hazard zones to eliminate or minimise damage to existing underground structures during digging
- availability of a database which contains topographical information and existing utility line networks

The development phase and initial field trials show that the Detectino system, which uses the latest mechatronics, IT and geophysical sensors, meets the requirements profile, and use of the device will be soon be offered as a service. (reu)

SYNGAS FROM ALGAE USED TO PRODUCE FUEL

Project motivation and initial results

Since the end of the 1990s, efforts have been underway to develop biomass exploitation technology. For material with suitable moisture content, especially silage, decentralised plants to generate power and heat have been developed to a high standard. Production of methane at a quality level equivalent to natural gas is becoming increasingly important. Thermal techniques for combustion or gasification are available for dry materials such as wood and straw. A lot of research effort has been invested in recent years to achieve process improvement. Through the ArtFuel programme, the State of Lower Saxony has provided subsidies for a pilot plant to promote the use of a broad range of biomass for syngas production. The plant was completed in December 2004, and it has demonstrated its operational capabilities on other projects.

The technical developments however must also be viewed in light of social considerations. Some of the major issues are:

Algae in the reactor feed conveyor

- the need to keep competition with food production to a minimum
- the need to increase overall efficiency from planting right through to the energy product, because only a limited amount of acreage is available for energy crops

Biomass from algae offers new, increased potential to produce fuel without creating a situation where energy production competes with food production. Arguments in favour of this type of biomass production include:

- significantly higher biomass yield per acre
- algae can be produced on brownfield sites
- reactors can be built vertically
- algae can be harvested from the sea

A lot of development work is currently being invested in the production of fatty acid methyl ester (FAME) from algae oil and the production of ethanol from the remainder of the biomass.

The State of Lower Saxony (Department of the Environment) and Volkswagen are subsidising a project to produce syngas from the entire plant with the intention of making synfuels from the syngas. The production of second-generation fuels (e.g. BtL*, LPG** and SNG***) from algae is expected to produce higher yields because the entire biomass can be used.

The argument surrounding the production potential of algae also applies to cogeneration applications.

It is also important to note that algae need CO_2 to grow. This gas is present at BtL plants and power stations. If production of the biomass becomes technically and economically feasible, the CO_2 could be used to promote growth, increase the overall efficiency of the production chain and reduce the carbon footprint.

The technical feasibility was demonstrated during initial trials. The material could easily be fed into the reactor (see illustration above).

However, it is proving difficult to process the harvested biomass. The intention is to use a mixture of material from algae farms and algae that is washed up on the sea or lakes. The problem is that sea and lake algae have a high sand content, resulting in low gas yields and poor gas quality. The project partners have discussed possible solutions. A new source of algae and a new treatment process are expected to improve the quality of the fuel. Trials at the ArtFuel plant will show whether the new approach will produce the expected results. (vd)

*Biomass to Liquid, **Liquefied Petroleum Gas ***Substitute Natural Gas

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Published by:
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Photos: G.-E. Knochen (kn)
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E-mail: cutec@cutec.de
Internet: www.cutec.de
Publication:
Several times a year at irregular intervals.
Issues can be ordered from the address above at no charge.
Send an E-mail to:
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CUTEC FOOTBALL TEAM PLAYS IN CHARITY MATCH

CUTEC team loses 3-5 to Förderverein Oase

"Winners" and "losers" get together after the match

On Friday, September 11th, football teams from CUTEC and Förderverein Oase met on the Ringerhalde pitch in Clausthal-Zellerfeld to play a charity match. The weather on the day was magnificent. The match was organised by Förderverein Oase, a charity which supports residents at the Klosterhof care facility in Clausthal-Zellerfeld. The annual football match played against different teams from the region is the highlight on the charity's sporting calendar. The hosts took a 5-0 lead in the 60-minute contest, before the CUTEC team, fired on by the CUTEC fans, was able to stage a rally. The final score was 5:3. The referee, dressed as a Viking and using a huge horn for the opening whistle, unsurprisingly attracted considerable attention.

The CUTEC Institute has fielded a football team since 2008. Scientists, research assistants and members of the technical staff play in the team. The management team sponsored the football kits to support the joint after-hours activity. CUTEC now projects a "uniform" image on the pitch. The team plays matches in the region at irregular intervals, and on occasion it also takes part in tournaments. Despite the fact that no regular training takes place, the team can be proud of two achievements this year, namely the second-place finishes in the Altenau and Petershütte tournaments. Ten teams competed for the honours in Altenau, and five teams took part in the Petershütte event.

However, our football enthusiasts are mainly interested in the enjoyment of the game, and there will be plenty more opportunities to have fun. The CUTEC team has been invited to two indoor tournaments that will be held in January. We plan to stay on the ball. (bau)

WE EXTEND OUR BELATED CONGRATULATIONS TO…

Managing Director and head of the Environmental Science Institute Prof. Carlowitz who recently celebrated his 60th birthday. Late in the afternoon of June 24th, the CUTEC staff and a number of guests got together for a small celebration. To get things underway, the "CUTEC Choir" sang a serenade under the direction of two members of staff who are experts on the guitar. This was followed by the customary speeches, at the end of which the Chairman of the Workers' Council presented a gift on behalf on the staff. Prof. Carlowitz received a special issue of a birthday newspaper in a late 1940s look. The editorial highlighted the achievements of selected Ottos throughout history. After the more official part of the ceremony, Professor Carlowitz opened the buffet, and the gathering continued in a relaxed atmosphere. A man dressed in a chef outfit suddenly appeared to reveal information about top secret projects in the depths of the CUTEC building, while the well-fed audience listened in breathless amazement. There were rumours circulating at the event that this person, who was so exceptionally well informed about the secret machinations at CUTEC, might well have been local pastor, scientist and cabaret artist Matthias Schlicht. (uR)

Workers' Council Chairman Dr. Zeller (left) presents the gift to Prof. Carlowitz

Werner Grübmeyer (right), long-standing CUTEC patron, extends his personal congratulations

NEW ADDITIONS TO THE TEAM

Operating departments receive welcome reinforcements

Britta Schulz

Britta Schulz has been lending a helping hand to International Affairs Coordinator Dr. Theodore I. Onyeche in her role as PA since January 2nd, 2009.

Britta received a degree in primary education from the University of Cologne and subsequently took part in teacher training in Minden. In 1996, she decided to make a career change, working as a secretary at various companies in Germany and outside the country. She spent time with Haessler Corporation in Canada, EXPO 2000 in Hannover and H.C. Starck GmbH in Goslar.

Nils Brandt

Nils Brandt joined the Modelling and Simulation Department on March 1st, 2009. Nils is working as a software developer on the Detectino project.

Dipl.-Ing. Sven Schulze

Sven Schulze is a familiar face at CUTEC. He worked for several years as a scientific assistant in the Physical and Biological Process Department.

Sven has a degree in chemical engineering from the University of Applied Sciences in Clausthal where he specialised in membrane technology, bioprocess technology and computer-aided chemical process design. He graduated in March 2009, and the subject of his thesis was the influence of active sludge ozonation on membrane filtration.

Since September 1st, 2009, Sven has been providing support to the Sustainability Management Cluster, and he is working as a research assistant on the “Zinc Recovery form Steel Scrap” project (see CUTEC-News June 2009).

Katharina Bednarsky, Daniel Gröters und Alina Zech (v.l.n.r.)

Again this year, the CUTEC Institute is providing vocational training for several school leavers. Katharina Bednarsky began training as an office administrator on August 1st.

Daniel Gröters began his vocational training as an industial mechanic on August 1st, 2009. Daniel will be learning his trade in the engineering workshop over the next three years.

Katharina and Daniel are already familiar with their new workplace, as they spent one year here during a work experience programme.

Alina Zech took the initial step on the path to her future career on August 1st, 2009. Alina will be taking part in a one-year work experience programme as part of her course at a technical college. She will be working in the administration section at CUTEC. (wes)

CONGRATULATIONS TO ...

Stefanie Auberg and Sabrina Uhlig who passed their summer examinations and have now completed their vocational training in office administration. Stefanie has left CUTEC to take up a position with a private company. Sabrina will remain in the administrative team at CUTEC. One of her duties will be to look after the library. (he)

Continuation from page 4

NEW MAN AT THE HELM OF CHEMICAL PROCESS ENGINEERING FOR THE PAST 2 YEARS

work in various capacities. Using this approach, we have acquired around € 1.2 million of external financing to support the department's activities. We have also presented more than ten talks and posters at international conferences and published articles in peer-reviewed professional journals.

Through our participation in the CUTEC Thermochemical Biomass Conversion cluster, cooperation with the Lower Saxony state fuel cell and battery technology initiative and work on a variety of joint projects, we have built up a large network of contacts with academic research institutes and the private sector. We will make good use of this network to acquire new projects, and we will continue to expand the network. (li)